Chapter 6

Michael Polanyi and the Epistemology of Engineering

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Summary

In his main monograph, Michael Polanyi promotes a new philosophy, the "fiduciary program," which is meant to tackle problems facing humanity. At its core, there is a new epistemology called Personal Knowledge, which is also the title of the book. This includes a comprehensive description of the epistemology of engineering as a distinct mode of knowing with its own characteristics, along with Polanyi's other two categories, "natural" and "exact" sciences.

In this article, Polanyi's engineering epistemology is reconstructed and evaluated. Polanyi states that all knowledge is either tacit or rooted in the tacit, and also explains how it originated from inarticulate animal knowledge. The knowledge of engineers is rooted in evolution in what Polanyi calls Type A learning, which involves a heuristic act of contrivance. For animals, this is essential for discovering means-ends-relationships.

For human engineers, the situation is not at all different. They harbor a particular kind of intellectual passion, the heuristic passion for discovering novel and economic ways of achieving goals.

What they discover are certain kinds of rules of rightness: operational principles of machines. This concept is part of Polanyi's hierarchical ontology. According to Polanyi, our material world has multiple levels of existence. Some things—living organizations and machines— are more real than everything else, because they are not merely material: they are emergent. In Polanyi's view, there is nothing extraordinary about these entities, as they are part of nature. As such, they should be accounted for by science just like any other phenomena. And, in fact, science does this, but it does not reflect this fact because it tends to employ a faulty methodology.

Emergent entities come into existence—or emerge—from matter. This is possible because the laws of matter leave room for higher level laws—rules of rightness—to operate. In the context of machines, these higher-level laws are called operational principles. The correctly implemented machine can operate flawlessly as long as the material conditions do not deteriorate outside limits.

The knowledge of the engineer is about these rules of rightness. From this, it follows that discovery in engineering means finding new operational principles. But the rules of rightness cannot account for faulty behavior. Failures always have material causes; therefore, the engineering profession entails a good grasp of material sciences. I will argue that this approach can be the conceptual basis for basic engineering research that is in contrast with applied science, the category engineering usually falls into.[1]

6.1 Introduction

This article extracts the aspects relevant for engineering epistemology from Michael Polanyi's main philosophical work. This monograph [175], titled *Personal Knowledge: Towards a Post-Critical Philosophy* (PK from this point) offers a completely novel, all-encompassing epistemology and also bold ontological statements. In this article, I don't rely much on any other Polanyi sources, except *Life's Irreducible Structure* [174] and *The Structure of Consciousness* [166]. Also, I refer to the work of Phil Mullins about *Michael Polanyi on Machines as Comprehensive Entities* [139] in the same volume this article appears an on Esther Meek's *Contact With Reality* [120]. The main reason for this is that there appears to be no major shifts in his thinking about the issues relevant to us - his subsequent works all tend to the same direction as set out in PK only in more detail and an altered terminology.

Polanyi aims to update the core of what we think about the nature and status of all knowledge in general. As the nature of knowing is at the foundations of all domains of knowledge, every profession is affected by this update. Polanyi is conscious about this situation, and explicitly mentions biology and other natural sciences, social science, history, mathematics, art and engineering, too.

The phrase "post-critical" in the subtitle summarizes the main statement very well. That is: while the critical, objectivist approach - Polanyi uses these terms broadly to portray all approaches that attempt to remove the *personal coefficient* from knowing - in epistemology has been a tremendously useful for humanity, it

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only succeeded because it has never been exercised in a perfectly systematic manner, leaving room for uncritical elements in the production of knowledge.

Since these uncritical elements are there by necessity, the efforts to remove them are bound to fail and sometimes produce negative side effects. These include making scientists mislead themselves and everybody else about the origin and status of their knowledge through moves that Polanyi calls *deceptive substitutions*; also in a broader social setting, the same systematic, maximally critical attitude inhibits the reflection on human passions that, of course, remain just as vigorous regardless of our awareness of them, leading to *moral inversion*. This in turn, in Polanyi's evaluation, is a contributing factor to the horrors of historical catastrophes, like those in the twentieth century in the two world wars and communism. To heal these very destructive forces and events, Polányi offers the *fiduciary program*.

6.2 Ontology in Personal Knowledge

Polányi's conceptual system in PK, as he himself admits it, is circular on the explicit level. In order to justify this situation, he explains that on a conceptual level, only circular systems of beliefs are possible - no one has any other kind of conceptual system.

In this case, Polányi suggests, those systems that reflect on their own circularity are more valuable for their honesty than those that pretend to have independent foundations but in reality are just as circular.

In Polanyi's account, animals have evolved to have an usually reliable grasp of reality as the opposite was not good for survival. Humanity, at the most advanced end of the spectrum of animals, therefore is usually right to rely on its skills in knowing reality [120].

It is evident that other animals don't use language and therefore their knowledge can be nothing else but tacit [81]. Human knowledge is also rooted in the tacit and can only ever be partially explicit. The consequence of these statements is that it is possible for humans to learn the truth about reality, but what they learn is always reliant on tacit knowledge and thus cannot pass wholly explicit tests or verification, and therefore relying on such tests as anything more than heuristic tools in knowledge production is an error in methodology. These tests of objectivity and experimental verification can never become such final arbiters of knowledge as they are sometimes expected to be.

Now, Polanyi's ontology is proposed in this modality. The following set of ontological statements is based on several scientists' work as well as Polanyi's own understanding of the world - but the fact that this is a good description of the world is on an explicit level only supported by the fact that this is how humans tend to understand it.

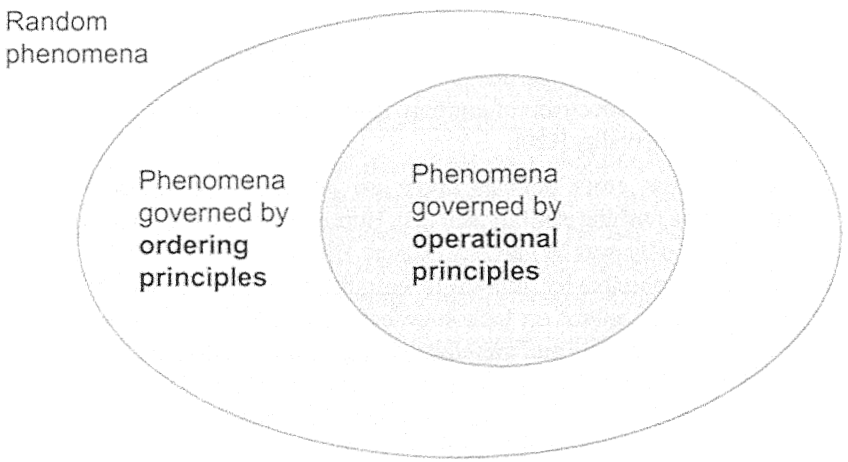
In nature, there are *ordering principles* in effect. These govern all non-random phenomena, which sometimes are labelled as *systems* by Polanyi. *"When I say that an event is governed by chance, I deny that it is governed by order"* (PK, p34).

An example of a natural phenomenon governed by ordering principles is the "*movement of planets around the sun* (PK p39)" Ordering principles have a subset called operational principles. These describe the "*correct functioning*" (PKp346) of entities that have a "*teleological character*" (PKp381).

The main statement about these entities is that they are of a class of things defined by a common operational principle and unspecifiable by the laws of physics and chemistry. (PKp346)

These entities include machines and living beings that are "classed with machines" [174]. Therefore these entities are the subject of engineering and biology, respectively. These disciplines investigate the operational principles in order to explain successful functioning and fall back to physics and chemistry to explain failures. He says the operational principles of machines are, therefore *"rules of rightness"*. (PKp346)

Where entities governed by plain ordering principles end and where entities governed by operational principles begin (see in the figure below) is never fully specified by Polanyi. But it is possible to find an example of the simplest machines, which is the gas flame:



"() its identity is not defined by its physical or chemical topography, but by the operational principles which sustain it." (PKp406)

Other examples offered are *cybernetics, typewriters, clocks, boats, telephones, locomotives, cameras* (PKp345)

6.3 Dual Control

These entities emerge from the physico-chemical level of existence to a higher level (see the explanation below at the "intensity of coherent existence"). The resulting situation is what Polanyi calls *dual control* in his 1965 essay Structure of Consciousness [169]. In order for the system to function properly, by its operational principles, the physical-chemical environment, as well as the parts of the system, needs to be within certain physico-chemical limits. These conditions enable the governance of the operational principles and therefore the explanation of the success of the entity requires these principles. The situation is explained in detail by [139].

However, failure is to be explained by physics and chemistry, and as a deviation from the necessary conditions or obstacles that prevent the successful work of operational principles.

Therefore, there are two different kinds of conditions operating on different levels. Both sets are necessary for the machine-like entity's proper functioning. Hence, the situation is controlled by both, as the term *dual control* suggests.

6.4 Operational Principles and Life

In case of living beings, the operational principles in question are researched by biology, but the dual control situation is the same: *"[a] machine-like function is characterized by its operational principle, (...). Therefore, as an organism sustains itself by functioning as a machine, it is the embodiment of an ordering principle that cannot be defined in terms of physics and chemistry."* (PKp426)

Moreover, there is an explicit link between technology and life, as "*every manifestation of life is a technical achievement, and is therefore - like the practice of technology - an applied knowledge of nature.*" (PKp426)

The examples for operational principles of life are equilibration (PKp359) during embryonic development, organ development, metabolism but also the more advanced forms of self-regulation like identifying food or prey and thriving to reproduce.

6.5 From Ontology to Epistemology

As we progress from randomness through ordering principles to operational principles, we see higher and higher "*intensity of coherent existence*" (PKp39).

Living things, especially animals themselves are examples of more coherently existing entities and, at the same time, their survival usually depends on recognizing other such entities. Moreover, in order to survive, they need to learn about how such entities behave, either as prey, dangerous predators, or tools. For animals, this knowledge is entirely tacit. Humans are able to express

and transmit their knowledge, but only partially. Yet, as Polanyi explains, this ability gave the gift of cultural inheritance.

Part of this inheritance is the sciences. The structure of knowledge of sciences reflects their subject [139]. Therefore engineering and biology contain teleological elements and the study of operational principles. Attempts to transform these disciplines (Polanyi discusses biology, but we can infer to engineering science as well), to be more like physics and chemistry - especially by removing the teleological element - have been damaging and if done systematically it results in a loss of grip on reality.

And just as the teleological element cannot be sensibly removed from these disciplines, the so-called *intellectual passions* should be preserved too. These again are rooted in animal passions like the drive by hunger, self-preservation and reproduction. As with knowledge, Polanyi sees continuity between animals and humans and human scientists in this respect, too. The scientists possess the *selective passion*, which helps to tell apart the interesting phenomena, theories and directions from the non-interesting ones and is a remote descendant of the selective mechanisms of animals, e.g., during hunting or searching for food. There is a kind of passion that facilitates problem-solving in both engineering and science and can be traced back to the heuristic capabilities that can be shown in animal experiments. These experiments reveal what Polanyi calls Type A learning, which involves a *heuristic act of contrivance*. For animals, this is essential for discovering means-ends-relationships.

For human engineers, the situation is not at all different. They harbor a particular kind of intellectual passion, the *heuristic passion* for discovering novel and economic ways for achieving goals.

Finally, there is the *persuasive passion* that drives the scientist to try and share his or her knowledge and convince others about the discovered truth, which is again traced back to the feeling of the comfort of conviviality already present in the animal kingdom.

6.6 Engineering epistemology

Based on the previous discussion, engineering is a form of *contrivance*. The subject of this contrivance is finding *operational principles* and *explaining failures*, often with physics and chemistry. Its subjects are *dual-controlled* machines. Engineering can be mostly associated with the *heuristic passion* but also draws on all intellectual passions.

Naturally, like all domains of knowledge, engineering heavily on *tacit knowledge*. Because of the nature of operational principles, it is necessarily teleological. This *teleological* nature is also the reason why it is often identified

as *normative*: if the goal is to create a machine, the operational principles become prescriptions for what to do, for how to achieve the proper functioning.

Also, we can establish that engineering is not just Applied Science (where "science" means physics, chemistry - as is often implied in English but less so in other languages). True, natural science is a necessary part of engineering used in explaining failures and investigating the physico-chemical preconditions of operational principles. But a major part of engineering is about these principles themselves about which physics and chemistry cannot say anything. This enables the viability of *basic engineering research*, which concerns operational principles.

6.7 Summary

Polanyi does not aim to say novel things about the philosophy of engineering in particular. He intends to reform all domains of knowledge, including engineering about which he consciously formulates some key statements. Both epistemic and ontological elements are provided for understanding the field.

The fact that there are different intensities of existence in Polanyi's account means that this is a multi-layered ontology, but one which is emergent on matter. This provides us with the concept of the dual-controlled emergent machine that is both based on matter and governed by operational principles. This is the subject of engineering and its characteristics should be reflected in the nature of engineering knowledge - containing teleological knowledge and material laws.

Just like any field of human knowledge, engineering relies on intellectual passions, mostly the heuristic passion which drives problem-solving, a focal activity of engineering.

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